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Research Article

Effect of Priming on Seed Germination and Seedling Growth of Cardamom (*Elletaria cardamomum* L. Maton) at Teppi, Southwestern Ethiopia

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Abstract

An experiment was conducted to determine the effect of seed priming on the germination and seedling growth of cardamom. The experiment consisted of two factors, namely; five priming solutions (distilled water, KNO_3 (0.2%), GA_3 (200 ppm), cow urine (10%), and tap water), and two soaking durations (6 hrs. and 9 hrs.). The factorial combination of these factors was arranged in a randomized complete block design and replicated four times. Different parameters were measured, including seed germination percentage, germination index, shoot and root length, fresh and dry weight of shoots and roots, as well as root volume. Notably, the main effect of the priming solution had a significant ($P<0.05$) effect on the aforesaid germination and seedling growth attributes. However, the main effect of soaking duration and their interaction with priming solutions did not exhibit a significant effect ($P>0.05$). Among the priming solutions, the application of cow urine at a 10% concentration exhibited a significant effect on the seed germination and subsequent growth of the cardamom seedlings. Advantageous results of seedling vigor indexes I and II were observed from cardamom seeds primed with the same solution. Accordingly, the growers and seedling producers in the study area are advised to apply a 10% cow urine priming solution before sowing cardamom seeds for enhanced germination and seedling growth.

Keywords

Cardamom, Germination, Priming Solution, Seed Priming, Seedling Vigor

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1. Introduction

Cardamom was introduced to Ethiopia in 1972; two cultivars were the Malabar and Mysore types, as reported by Edossa [1]. The crop is primarily grown for its fruit, which is used as a flavoring and seasoning agent in a wide range of spicy cuisines, including vegetables, meat dishes, tea, butter, coffee, bread, and cakes. Beyond its culinary role, the aromatic nature of cardamom contributes to the production of essential oleoresins and volatile oils, which are important ingredients in the pharmaceutical and perfumery industries. This crop commonly grows in the western and southwestern regions of Ethiopia under the natural cover of forests, thriving at altitudes up to 1400 meters above sea level. The annual rainfall in this region ranges from 1500 to 7000 millimeters, which creates an ideal growing environment for the crop [2]. It thrives in an area with a warm and humid environment with abundant rainfall and fertile soil. As a shade-loving plant, cardamom requires an optimum shade level of 50 to 60% for enhanced growth and yield performance [3]. The cardamom plant can reach heights of up to 3 meters, and its flowering and fruit setting usually commence 2 or 3 years after planting. The light green or yellow fruits, containing 15 to 20 small seeds, are responsible for the desirable flavor and fragrance associated with cardamom [4].

Cardamom can be propagated vegetatively through suckers from its clump or via seeds. Lateral suckers or shoots (containing both old and young) can be detached from an established farm or seed orchard and promptly transplanted into prepared pits to facilitate vegetative propagation. Nevertheless, this method might fall short of generating a sufficient quantity of planting materials for wider regions or meeting demand. Moreover, this method may also facilitate the transmission of diseases and pests to the new plantation since the plant is highly sensitive to thrips and the mosaic virus, as reported by Subramaniyan et al. [5]. Conversely, the most typical and widely adopted method among growers and farmers is to raise cardamom seedlings in a nursery. According to Tiwari and Agarwal [6], cited in Shiferaw et al. [7], a large number of seedlings can be raised without fear of disease spread compared to vegetative propagation. To ensure an ideal seed preparation, the collection of seed capsules should be confined to the peak harvesting season (October and November). Well-ripened seed capsules from mature (>5 years old), healthy, and high-yielding plants should be collected during this time [8].

Nevertheless, the cardamom seed has a low germination rate, as evidenced by the previous works of Nilanthi [9] and Hassen et al. [10]. According to Gupta et al. [11], the germination percentage of cardamom seeds could be as minimal as 20–25%. Furthermore, the slow germination process and uneven seedling emergence pose significant challenges to the production of cardamom seedlings. This problem might be caused by both exogenous and endogenous dormancy. According to Gupta et al. [11], the hard coat and mucilaginous coating on the external part of the seeds are the primary causes of exogenous dormancy. Whereas endogenous dormancy is mostly related to germination-inhibiting compounds and low food reserves in the endosperm, as reported by Hilhorst et al. [12] and Eyob [13]. Given these problems, it is essential to apply the appropriate seed treatments before sowing to improve both germination and seedling emergence. This strategic approach could increase the production of cardamom seedlings, which would increase the supply of seedlings in general.

Seed priming is one of the pre-sowing seed treatments that is applied to fasten germination, achieve uniform emergence, and boost seedling vigor [14]. According to Basra et al. [15] and Ashraf and Foolad [16], there are numerous ways to prime seeds, including hydro-priming, hormone priming, osmo-priming, and bio-priming. In recent years, many experts have advocated that seed priming be viewed as a helpful tactic for successful germination and healthy seedling growth, which would lead to increased yields [17]. However, there hasn't yet been any scientific information provided on the effects of various priming solutions on cardamom seeds. Therefore, while using this approach, choosing the appropriate priming solution and allowing it to soak for the necessary amount of time are essential to attaining a decent result on this crop. Accordingly, this study was conducted to identify a suitable priming solution and appropriate soaking duration that can enhance seed germination, emergence, and subsequent growth of cardamom seedlings.

2. Materials and Methods

The study was conducted at the Teppi Agricultural Research Center (TARC) under nursery conditions from October 2020 to August 2021. The center is in the Southwestern Ethiopia Peoples Regional State, Sheka administrative zone, at Teppi town. The town is located about 611 kilometers away from Addis Ababa, the capital city of Ethiopia. The geographical coordinates of the center are situated at 7°10' N latitude and 35°25' E longitude. The altitude of the site is 1,200 meters above sea level and is characterized by a hot, humid climate with an average annual rainfall of 1,559 mm. The mean maximum and minimum temperatures are recorded at 30.23 ℃ and 16.09 ℃, respectively [18].

2.1. Experimental Treatments, Design and Procedures

The experimental treatments consisted of six priming techniques (KNO_3 (0.2%), GA_3 (200 ppm), cow urine (10%), distilled water, tap water, and control/unprimed) and two soaking durations (6 hrs. and 9 hrs.). The two-factor treat-

ments were arranged factorially in a completely randomized design (CRD) with four replicates. Fully matured cardamom fruits were collected from healthy mother plants at Teppi ARC during the peak harvesting period (November 2020). After harvesting, the seeds were carefully removed from the fruit or capsule pericarps and washed thoroughly to remove the mucilage around the seeds. Subsequently, about 400 clean seeds of uniform size were selected for each treatment and soaked separately in the respective priming solutions and soaking durations. Each treatment was replicated four times, with 100 seeds for each treatment. Following the priming procedure, both primed and unprimed seeds were sown directly on plastic pots filled with a mixture of forest soil, animal manure, and fine sand in a 3:2:1 ratio [19] under nursery conditions. The released cardamom variety, called Gene, was used for this experiment. Routine nursery practices were applied as per previous recommendations [10, 19].

2.2. Solution Preparation

In order to make the solution of KNO_3 at 0.2% (w/v), two grams of KNO_3 poured into a container with a holding capacity of 1000 milliliters. Subsequently, the solution was thoroughly diluted or dissolved using distilled water until the total volume reached up to 1000 milliliters. Similarly, about 0.2 grams of GA_3 were poured into another container with a similar holding capacity and thoroughly dissolved using distilled water until the total volume reached up to 1000 milliliters. Regarding cow urine solution, about 100 milliliters of cow urine were measured using a volumetric flask to make a 10% solution of cow urine. Then, the measured cow urine was thoroughly poured into another container with the aforementioned holding capacity. Successively, the distilled water was added to the cow urine and then stirred and dissolved carefully until the total volume of the cow urine solution (10%) reached 1000 milliliters. Moreover, a total volume of 1000 milliliters of distilled water was prepared using a water-distilling machine and thoroughly poured into the container with a similar holding capacity. The tap water with a volume of 1000 milliliters was measured using a volumetric flask and then transferred directly into the soaking container. Finally, all containers were labeled with the relevant information, including the solution's name, concentration, and date.

2.3. Data Collection

Standard germination (%): number of seeds germinated out of 100 seeds of each replication starting from the first day of germination to the end of the germination period; it was the 42nd day of germination. It was computed as described in the [20] manual, as follows:

$$\text{Germination Percentage (\%)} = \frac{Total\ number\ of\ normal\ seedlings}{Total\ number\ of\ seeds\ kept\ for\ germination}\ x\ 100$$

Germination index (GI): it was determined with a similar procedure to the standard germination test, but the number of germinated seeds was counted and removed every day until there was no further germination [20].

$$\text{Germination index (GI)} = \frac{(No.of\ germinated\ seeds)}{(days\ of\ first\ count)} + \cdots + \frac{(No.of\ germinated\ seeds)}{(days\ of\ last\ count)}$$

Mean germination time (MGT): it was calculated according to the equation of [21]:

$$\text{Mean Germination Time (MGT)} = \frac{\sum f_i\, x_i}{N}$$

Where; f_i - is the day during germination period (between 20 and 42 days), x_i - is the number of germinated seeds on day f_i, N - is the total number of germinated seeds.

Regarding growth parameters, the shoot and root length of seedlings, the fresh and dry weight of both the shoot and root of seedlings, and the root volume were measured on twenty-five randomly selected seedlings when they produced 4-5 leaves or were 6 months old [22]. According to the author, this growth stage represents the point at which the cardamom seedlings achieve their highest growth and biomass yield, indicating their readiness for transplantation.

Shoot length (cm): It was measured from the collar to the tip of the primary shoot.

Root length (cm): It was measured from the collar to the tip of the primary root.

Fresh weight of shoot (g): sample seedlings were uprooted from each treatment, and the shoot and root parts were separated by cutting down using a knife. Then, the fresh weight of the shoot was measured on an electronic balance.

Fresh weight of root (g): the root part was washed to remove the soil and derbies adhering to it, and allowed for shade or slight drying to remove excess water residing on the root surface. Following that, the fresh weight of the root was measured on an electronic balance.

Dry weight of shoot (g): the freshly weighed shoots were chopped into small pieces and kept in paper bags. Then, it was dried in a hot air oven maintained at 80 ^{o}C for 24 hours and cooled down. After that, the dried shoot was weighted on an electronic balance [20].

Dry weight of root (g): the freshly weighed roots were chopped into small pieces and kept in paper bags. Then, it was dried in a hot air oven maintained at 80 ^{o}C for 24 hours and cooled down. After that, the dried shoot was weighted on an electronic balance [20].

The seed vigor index values were also determined using the following [23] formula, in accordance with the [20] guideline:

Vigour index I = GP x SL, and Vigour index II = GP x SDW (g)

Where: GP - germination percentage, SL - seedling length,

SWD - seedling dry weight

2.4. Data Analysis

All the collected data were first checked for fitting the normality assumptions of the ANOVA. Then, all data were subjected to analysis of variance using SAS statistical software version 9.2 [24] as per standard procedures. To compare the means of the treatments, the least significant difference (LSD) test was applied at a 5% significance level, following the approach outlined by [25].

3. Results and Discussion

3.1. Seed Germination Parameters

The results of the analysis of variance revealed that the seed germination percentage and germination index, or speed, were significantly ($p<0.05$) influenced by the main effect of priming solutions. Nevertheless, the main effect of soaking durations and their interaction with the priming solutions had non-significant ($p>0.05$) effects on the seed germination percentage and germination index or speed. Thus, the 10% cow urine solution was found to be significant over other priming solutions for the germination percentage and germination index or speed (Table 1). The maximum germination percentage (86%) was recorded from seeds primed with the 10% cow urine solution, followed by unprimed or untreated seeds, but they were statistically at par. Similarly, the highest speed of germination (30.08) was also observed in the seeds primed with the aforementioned cow urine solution (10%). Conversely, the seeds that were primed with distilled water and tap water exhibited the minimum germination percentage and germination index (speed), respectively (Table 1). On the other hand, the mean germination time was not significantly ($p>0.05$) influenced by the main effects of the priming solution and soaking duration, as well as their interactions (Table 1). Nevertheless, the shortest mean germination time was recorded for the seeds that were primed with the 10% cow urine solution before sowing.

Table 1. *The germination of cardamom seed as influenced by the main effects of priming solutions at Teppi during 2020/21.*

	Germination (%)	**Germination Index (Speed)**	**Mean Germination Time**
Priming Solutions			
Control	70.50^{ab}	16.68^{b}	89.19
Distilled	39.50^{c}	7.73^{c}	98.76
KNO_3 (0.2%)	49.50^{c}	11.06^{bc}	94.23
GA_3 (200ppm)	54.00^{bc}	10.48^{bc}	100.89
Cow Urine (10%)	86.00^{a}	30.08^{a}	58.27
Tap Water	44.00^{c}	7.22^{c}	96.22
$LSD_{(0.05)}$	*	*	ns
Soaking Durations			
Six Hours	60.00	12.63	92.13
Nine Hours	54.50	15.12	87.05
$LSD_{(0.05)}$	ns	ns	ns
CV (%)	31.91	56.06	31.67

Means followed by different letters within a column are significantly different ($P\leq0.05$).

The maximum seed germination percentage and germination index (speed) observed on the seeds primed with 10% cow urine can be attributed to the presence of biologically active substances such as growth regulators and essential plant nutrients in the cow urine solution [26-28]. These elements contribute to the softening of the seed coat, enhancing its permeability through diffusion, and promoting the early emergence of radicles. The early emergence of the radicles, in turn, also triggers the seed germination process, as outlined by Basavaraj et al. [29], who are cited in Thanuja et al. [30]. Moreover, the early breakdown and mobilization of the reserved food could be the cause of a reduction in the mean germination time [26]. Our findings are in agreement with the findings of Hassen et al. [10] and Sharma and Deshpande

[31], who reported that the 10% cow urine treatment exhibited a significantly higher percentage of seed germination for korarima (72.5%) and pigeon pea (90.6%), respectively, in comparison with the unprimed or control treatment. Similar results have also been reported by Pavan et al. [28] on millet; Ambika and Balakrishnan [32] on cereals; Amarnath et al. [33] on sorghum; Ambika et al. [34] on cluster beans; Arvind et al. [35] on sorghum, and Vishwanath et al. [36] on cotton.

3.2. Shoot Growth Attributes

Based on the analysis of variance, the main effect of soaking duration and its interaction with priming solutions had a non-significant ($p>0.05$) influence on the growth of cardamom seedlings. Nevertheless, the priming solution exhibited a significant ($p<0.05$) effect on shoot length and the fresh and dry weight of shoots (Table 2). The tallest seedling (75.66 cm) was observed in seeds primed with the 10% cow urine solution before sowing, followed by the seedling (68.18 cm) raised from seeds primed with the KNO_3 (0.2%) solution. Similarly, the highest fresh (52.66 g per plant) and dry (7.18 g per plant) weights of shoot were recorded from seedlings raised from seeds primed with the 10% cow urine solution. On the contrary, the unprimed seeds produced the shortest seedlings with the lowest fresh and dry weights of shoots compared with primed seeds (Table 2). The cardamom seeds primed with the 10% cow urine solution exhibited significant increases in seedling length, fresh weight, and dry weight of the shoot by 27.8%, 95.6%, and 95.6%, respectively, compared with the unprimed seeds (Table 2).

The enhanced growth attributes of seedlings resulting from the 10% cow urine solution treatment can be attributed to the occurrence of growth substances like auxins and essential nutrients such as nitrogen, phosphorus, potassium, and micronutrients in the cow urine. These nutrients ultimately led to greater shoot length as well as increased fresh and dry weights of the seedlings, as discussed by Vikas et al. [27] and Pavan et al. [28]. According to Vishwanath et al. [36], cited in Pavan et al. [28], these substances also reduce the resistance of the endosperm envelope to expansive growth, which lowers the turgor threshold for early germination, resulting in enhanced shoot and root growth. Moreover, the hastened seed germination caused by the cow urine priming possibly contributed to the production of larger seedlings; this resulted mainly due to the enhanced activity of alpha-amalyse, as reported by several authors [26, 28, 37].

Table 2. *The fresh weight, dry weight and length of cardamom seedlings as influenced by the main effects of priming solutions at Teppi during 2020/21.*

	Seedling Length (cm)	Fresh weight of seedlings (g plant^{-1})	Dry weight of seedlings (g plant^{-1})
Priming Solutions			
Control	59.20^{c}	26.92^{c}	3.67^{d}
Distilled	60.51^{c}	33.48^{c}	4.56^{cd}
KNO_3 (0.2%)	68.18^{b}	44.88^{b}	6.12^{b}
GA_3 (200ppm)	66.48^{bc}	43.75^{b}	5.97^{bc}
Cow Urine (10%)	75.66^{a}	52.66^{a}	7.18^{a}
Tap Water	61.03^{bc}	34.64^{c}	4.72^{cd}
$LSD_{(0.05)}$	*	*	*
Soaking Durations			
Six Hours	65.94	38.72	5.28
Nine Hours	64.41	40.06	5.46
$LSD_{(0.05)}$	ns	ns	ns
CV (%)	11.13	11.42	40.14

Means followed by different letters within a column are significantly different ($P\leq0.05$).

Early germination and emergence also provide a prolonged growing period for seedlings, resulting in increased seedling growth and dry matter production [38]. This result was supported by Hassen et al. [10], who confirmed that the tallest korarima seedling (6.67 cm) was raised from seeds primed with a 10% cow urine solution under laboratory conditions. Further corroboration is found in the work of Jayanth et al. [39], who observed increased fresh and dry weights of

cotton seedlings raised from primed seeds with a 6% cow urine solution. Similar findings have also been reported by Pavan et al. [28] on millet seeds; Sharma and Deshpande [31] on pigeon pea seeds; Amarnath et al. [33] on sorghum seeds; Vishwanath et al. [36] on paddy rice seeds and Tagore et al. [40] on millet seeds.

3.3. Root Growth Attributes

The root growth attributes of the cardamom seedlings were significantly ($p<0.05$) affected by the main effects of the priming solutions. Nevertheless, the main effects of soaking durations or their interaction with priming solutions had a non-significant ($p>0.05$) influence on the root growth of cardamom seedlings (see Table 3). Among the priming solutions, the 10% cow urine solution showed a significant difference from other priming solutions with regard to root growth attributes such as root length and fresh and dry weight of roots. Thus, the longest root (39.35 cm) of a seedling was measured from seeds that were primed with 10% cow urine solution, followed by the root length (33.94 cm) from seeds that were primed with KNO_3 (0.2%) solution before sowing (Table 3). Similarly, the cardamom seeds primed with the aforesaid cow urine (10%) solution produced the highest fresh weight (21.9 g per plant) and dry weight (2.63 g per plant) of roots. The larger root volume (15.31 ml per plant) was also recorded from seeds that were primed with the same solution, followed by the root volume of 13.38 ml per plant from seeds that were primed with a KNO_3 (0.2%) solution before sowing. On the contrary, the unprimed or untreated seeds produced the shortest roots with the lowest fresh and dry weights. Lower root volumes were measured from both primed seeds with distilled water and unprimed or untreated seeds (Table 3).

Table 3. *The main effects of different priming solutions on length, volume & fresh weight of roots of cardamom seedlings at Teppi during 2020/21.*

	Root length (cm)	Fresh weight of root (g plant^{-1})	Dry weight of root (g plant^{-1})	Root Volume (ml plant^{-1})
Priming Solutions				
Control	25.29^{e}	9.17^{d}	1.10^{d}	7.08^{d}
Distilled	26.28^{de}	10.00^{cd}	1.20^{cd}	6.77^{d}
KNO_3 (0.2%)	33.94^{b}	16.23^{b}	1.95^{b}	13.38^{ab}
GA_3 (200ppm)	31.31^{bc}	14.00^{bc}	1.68^{bc}	11.04^{bc}
Cow Urine (10%)	39.36^{a}	21.90^{a}	2.63^{a}	15.31^{a}
Tap Water	28.92^{cd}	10.74^{cd}	1.30^{cd}	8.80^{cd}
$LSD_{(0.05)}$	*	*	*	*
Soaking Durations				
Six Hours	30.53	13.78	1.65	10.19
Nine Hours	31.17	13.56	1.63	10.61
$LSD_{(0.05)}$	ns	ns	ns	ns
CV (%)	11.53	34.00	30.20	23.91

Means followed by different letters within a column are significantly different ($P\leq0.05$).

The improved root growth of cardamom seedlings exhibited on primed seeds with a 10% cow urine solution could be attributed to the activation role of the free radicle scavenging enzyme during the seed priming process [26, 28, 36]. Accordingly, this enzyme's activation leads to increased extensibility of the embryonic cell wall and the early emergence of radicals. Consequently, these factors contribute to the improved development of roots and their capacity for dry matter production. Furthermore, the vigorous growth of roots can also be associated with the presence of auxins and nutrients in cow urine. This phenomenon has been supported by studies conducted by Vikas et al. [27], Thanuja et al. [30], and Shinde and Malshe [41]. Their research has demonstrated that the elongation and volume increase in roots due to cow urine components lead to higher dry matter production. Our results align with the findings of Sharma and Deshpande [31], who observed that treating pigeon pea seeds with a 10% cow urine solution resulted in increased root length in seedlings. Similarly, Rajput and Sharma [42] also found that priming the custard apple seeds with 100% cow urine before

sowing led to greater fresh and dry root weights of the seedlings. Our results align with the findings of Rajput and Sharma [42], who noticed a larger fresh and dry root weight of custard apple seedlings after the seeds were primed with 100% cow urine prior to sowing. Comparable results have also been reported by Pavan et al. [28] on millet seeds; Ambika and Balakrishnan [32] on cluster bean seeds; Arvind et al. [35] on sorghum seeds; Jayanth et al. [39] on cotton seeds and Tagore et al. [40] on millet seeds. These collective studies emphasize the concept that the utilization of cow urine for seed priming can produce enhanced root growth and subsequent dry matter production.

3.4. Seedling Vigor Indices

Similar to other parameters, the vigor indices (index I and II) of cardamom seedlings were also significantly ($p<0.05$) affected by the main effects of priming solutions. However, the main effects of soaking duration or their interaction with the priming solutions had a non-significant ($p>0.05$) influence on both vigor index I and II (Table 4). The cardamom seeds that were primed with a 10% cow urine solution also showed a statistically significant difference over other priming solutions with regard to seedling vigor index I and II. Thus, the maximum vigor index I (9789.50 cm) and vigor index II (1963.68 g) were recorded from primed seeds with the 10% cow urine solution. Conversely, the seeds that were primed with distilled water produced the lowest values for seedling vigor index I (3490.70 cm) and seedling vigor index II (356.04 g), as indicated in Table 4.

The enhanced seedling vigor indices of cardamom seeds when primed with the 10% cow urine solution could be due to the cumulative effects of increased germination percentage, seedling length, and dry matter produced in comparison with the other seeds primed with different priming solutions. On the contrary, the reduced germination percentage observed in seeds primed with distilled water can be a possible reason for lowered seedling vigor indices. This result is in accordance with the findings of Hassen et al. [10], who reported a higher seedling vigor index I (579.30cm) and II (79.57g) on korarima seeds due to priming with cow urine at 10% concentration in laboratory conditions. Our finding was also supported by Nikshita et al. [43], who observed improved seedling vigor index I (1809.94cm) and II (104.09g) on sapota seeds after priming with the 10% cow urine solution before sowing. Similar results have also been reported by Pavan et al. [28] on millet seeds; Ambika and Balakrishnan [32] on cluster bean seeds; Jayanth et al. [39] on cotton seeds and Rajput and Sharma [42] on custard apple seeds.

Table 4. *The main effects of different priming solutions on the vigor indices of cardamom seedlings at Teppi during 2020/21.*

	Seedling Vigor Index I (cm)	**Seedling Vigor Index II (g)**
Priming Solutions		
Control	5963.00^{b}	595.80^{b}
Distilled	3490.70^{d}	356.04^{b}
KNO_3 (0.2%)	5039.10^{bcd}	705.24^{b}
GA_3 (200ppm)	5337.40^{bc}	832.32^{b}
Cow Urine (10%)	9789.50^{a}	1963.68^{a}
Tap Water	3851.80^{cd}	404.88^{b}
$LSD_{(0.05)}$	*	*
Soaking Durations		
Six Hours	5820.60	881.76
Nine Hours	5336.60	737.52
$LSD_{(0.05)}$	ns	ns
CV (%)	30.98	61.44

Means followed by different letters within a column are significantly different ($P\leq0.05$).

4. Conclusion

The results of this study indicate that seed germination and seedling growth attributes were significantly ($p<0.05$) affected by the priming solution used. Nevertheless, the soaking duration and its interaction with the priming solution did not

significantly influence the aforesaid parameters. The cow urine solution at a 10% concentration was found to be the most effective among the tested priming solutions. The cardamom seeds that were primed with the same priming solution produced the highest germination percentage and increased the growth of cardamom seedlings in comparison with the other priming solutions. Accordingly, the growers and seedling producers in the study area are advised to apply a cow urine priming solution at a 10% concentration before the cardamom seeds are sown for enhanced germination and seedling growth.

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Conflicts of Interest

The authors declare no conflicts of interest.

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